Stealth Technology and Air Warfare

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INTRODUCTION

Technological change is one of the constants of modern warfare. Each rifle has a little more range or a higher rate of fire than its predecessor. Each tank, a little more armor or better sensors. New airplanes have more agility, range, payload, and speed. Modifications to gear constantly update capabilities whether its a new mode on a radar, a decoy system on a ship, or a better magazine for a rifle.

Most technical improvements simply enable the soldier to do his job better but in about the same way he always has. Some changes require or, at least, make possible changes in the way the soldier fights, that is in his tactics. Acquisition of retarded bombs allows airmen to use level deliveries staying close to the ground without worrying (so much) about the bombs blowing them out of the sky. Equipment changes on the other side also drive tactics. A new SAM may force new penetration profiles. An improved enemy missile may dictate new formation tactics. These changes occur so often that even the annual review cycle for US fighter tactics manuals (MCM 3-1) has trouble keeping up.

Less frequently, but with profound impact, come technical innovations that change how armies (and navies/air forces) fight. These innovations change war at the operational level and can be seen in how campaigns are conducted. The introduction of the breech loader strengthened the defensive capabilities of small units and allowed Von Moltke to adopt a

campaign style that brought his forces together for the first time on the battlefield, upsetting the Napoleonic system to the dismay of the Austrians and the French in 1866—1870. Three generations later, the Germans would harness the tank, the airplane and the radio to create the shattering thrusts of the blitzkrieg. In that same war the creation of long-range escort fighters made possible the round-the—clock strategic bombing campaign against Germany.

Once in a great while a technology, or more often a group of technologies, will emerge so revolutionary that it changes not only how the soldier and army fight but how nations fight. The transition from sail and timber navies to steam and iron is a fair example. Perhaps the most obvious example comes from our own time, where the combination of nuclear weapons and long—range airpower (missiles and planes) fundamentally altered the way nations think about their security.

Starting in 1940, when rudimentary radar stations gave the RAY warning and direction in the Battle of Britain, one of the basic assumptions of warfare has been that approaching aircraft will be detected. For half-a-century one group of engineers and tacticians have tried to overcome the impact of radar. At the same time another has constantly improved radar technology and applied it to more and more uses in the battlefield of the sky. Five decades of innovation and counters have led to a battlefield environment where netted ground and airborne surveillance and acquisition radars feed command and control

centers that direct highly sophisticated, radar equipped SAMs, AAA, and interceptors against intruders. On the other side one finds support aircraft whose sole mission is to jam or destroy radar equipped facilities. Attacking aircraft carry their own jamming systems and follow extremely demanding penetration tactics to minimize their exposure to radar threats.

As the twentieth century ends, new aircraft technologies are assaulting the primacy of radar. If successful, these technical advances will certainly change how airmen fight. More importantly, freed from the threat of effective radar detection, air forces could change how they fight. This technology, the tactical superiority it spawns, and the operational advantage it brings may well have strategic implications for nations possessing it. Stealth, the combination of technologies that reduce the electro–magnetic signatures of aircraft, reenforced with associated trends in airpower promises such a revolutionary change in warfare.

STEALTH TECHNOLOGY

At the engineering level, the creation of stealth aircraft is a complex and demanding job. New materials, new electronics, and new aerodynamic shapes are all involved. Luckily, for the purposes of this paper, the technology is fairly straight forward at the conceptual level.

There are three basic methods of reducing an aircraft's radar cross-section (RCS). An airplane can be designed structurally so radar waves are deflected rather than reflected

back toward the threat radar.

Another solution is to use materials that do not reflect the radar energy. The final method is to eliminate emissions from the aircraft that could be sensed by an enemy.

Low-observable (L/O) shaping relies on faceting, cavity control, and smoothing to reduce RCS. Faceting is perhaps the simplest to understand. Basically the aircraft structure is designed so radar energy hitting the plane's surface from one direction is reflected away in another direction. The result is a collection of flat, plate—like sections of fuselage. Faceting also contributes to decisions concerning wingsweep. The more swept the wing, the more radar beams will be reflected away from the radar source. The tail surfaces provide another challenge overcome to some degree by faceting. Conventional tail design consists of vertical or near-vertical structures (one for the F-16, two for the F-15/l8) for yaw control and near-horizonal structures for pitch and, sometimes, roll control. By combining the functions of these two sets of control and stability surfaces into a single set of tails canted about 45 degrees from the vertical, much of the radar energy normally returned by the tail can be deflected. An even better approach, for stealth considerations, is doing away with the tail and accomplishing its functions with control surfaces integral to the fuselage.

Even if all the large surfaces of an aircraft could be faceted to reduce RCS, the designer would still face the problem

of all the nooks, crannies and protrusions on a modern aircraft. These radar "cavities" often collect and reflect radar energy very efficiently adding immensely to the RCS. While small airscoops/dumps, gun ports, and instrument ports/tubes all contribute to RCS, the challenging big offenders are the engine inlets, the cockpit, and the radome/radar.

Engine inlets scoop air and feed it to the jets. Unfortunately the also collect radar energy and feed it to the engine where the whirling compressor blades reflect it right back out the intake towards the illuminating radar. If a designer has the luxury of only having to worry about threats from below (e.g. ground-based missile systems) he can mount the intakes on top of the wing and effectively hide them. Likewise if the threat is look-down, under-wing inlets may work. For air-to-air or multi-role fighters the problem is more difficult as they face threats from above, below, and all around. In this case a partial solution is a serpentine inlet that bounces the radar beams around, shielding the compressor from direct illumination and scattering the returning energy. Used in conjunction with radar absorbent material (RAM), such inlets can effectively swallow radar waves.

While a cockpit covered with a smooth canopy may not look like a cavity to the eye, to a radar looking through a light and radar transparent canopy the cockpit is a hole filled with highly reflective panels, instruments, and controls.

One way of preventing this is to apply a thin layer of gold to the canopy transparency, a technique already

> used on the EA–6B Prowler....This will have minimal effect on visibility but will be "seen" by the radar as being an electrically conductive surface rather than an transparency - virtually an extension of the aircraft's skin.[1]

Gold-plated aircraft - defense critics will go wild! It works however to solve the problem of the cockpit cavity.

The last major cavity is the radome/radar cavity. Again looks are deceiving. The smooth, aerodynamic nose of a modern jet looks nothing like a cavity but to a radar it is a transparent skin covering a custom made radar reflector, the aircraft's radar antenna. Typically a parabolic dish, the radar antenna is designed to transmit and receive radar energy for use by the aircraft's systems. The same properties needed for its function make that antenna a great collector and reflector of radar beams illuminating the aircraft.

Two solutions are being worked. Flat–faced, phased-array antennae can be canted one way while highly computer–dependent, electronic beam-steering technics allow it to look another. The antenna then becomes another facet as already described. A second solution, even more dependent on micro–electronics and computer processing, is a distributed radar system. Using hundreds of miniature radars netted together, the designer can do away with a single antenna and its RSC penalty. Careful placement of these radars can avoid any significant return from any single aspect.

The final radar cavity producer that a designer must face is external stores carriage. All the missiles, bombs, and fuel

tanks that are hung on the underside of the wing, along with their associated pylons and racks, form huge cavities to reflect radar. The obvious solution is to provide for internal carriage or at least conformal carriage where stores are partially submerged into wells in the fuselage.

The last structural problem faced by a designer is how to handle travelling waves; the answer is smoothness. Travelling waves are electro—magnetic fields set up on a conductive surface when it is illuminated by radar. While most of the radar energy is reflected away at an angle equal to the angle of incidence, some transfers to the travelling wave. This wave moves along the surface until it dissipates or meets a discontinuity. When it hits such a discontinuity, a seam, an edge, or a sharp end, the wave re-transmits its signal back in the direction from which it came, back towards the illuminating radar.

Solutions for the travelling wave are conceptually easy but difficult in practice. The first answer is to get rid of any discontinuity. Smooth everything on the aircraft so the wave doesn't pile up. Easy to say - difficult to produce and maintain. Working with such close tolerances will be difficult in stealth factories and will only be possible through the use of advanced production control techniques including computer aided manufacture. The real challenge will be maintaining those tight fits on the flight line ten years after the aircraft leaves the factory. The other solution to travelling waves is to aid in their dissipation and for that RAM becomes a player.

For reductions in RCS beyond those achievable through structural design, materials must be used that will not reflect radar energy. These fall in two categories, radar transparent and radar absorbent.

Radar transparent material would seem to be the easy answer for stealth. Build the aircraft out of non–conductive composites and radar is no longer a problem. Unfortunately, for the stealth designer, transparencies have a problem. Just as with the radome that looked like a smooth surface but to a radar revealed a highly reflective antenna, radar transparent panels are of little use if they simply reveal more reflective internal parts of the aircraft. Structural spars, black boxes, and engines are just a few of the radar reflective liabilities that unthinking use of transparencies could uncover.

> The role played by composites in reducing RCS is a more subtle one. Carbon is a poor conductor of electricity....As a result, the electrical conductivity of composite materials is low. Radar energy arriving at a composite panel or structure has a hard job setting up the electrical and magnetic currents which re–radiate the energy and form troublesome creeping and standing waves.[2]

Radar transparent material then is best used as a covering to reduce travelling waves and in areas where reflective innards are not present. For other areas, materials that gobble–up radar energy are called for.

Radar absorbent material (RAM) is perhaps the leading edge of stealth technology. Materials engineers are heavily involved in developing strong, lightweight, heat-resistant composites

that will collect and dissipate radar energy. While there are many materials under development, they tend to all combine conductive and non-conductive materials in ways that break up radar waves. In some cases, metal fibers are imbedded in a composite material. In others, layers of conductive, reflective, and non—conductive materials will be combined to allow radar energy in but not out. RAM however is not the last word in stealth materials.

> By combining RAM with rigid radar-transparent substances, it is possible to create Radar-Absorbent Structural (RAS) materials, one of the most classified forms of radar absorber....US press reports have described how RAS material based on laminated layers of glass fiber and carbon—coated plastic are used on the leading and trailing edges of stealth aircraft.[3]

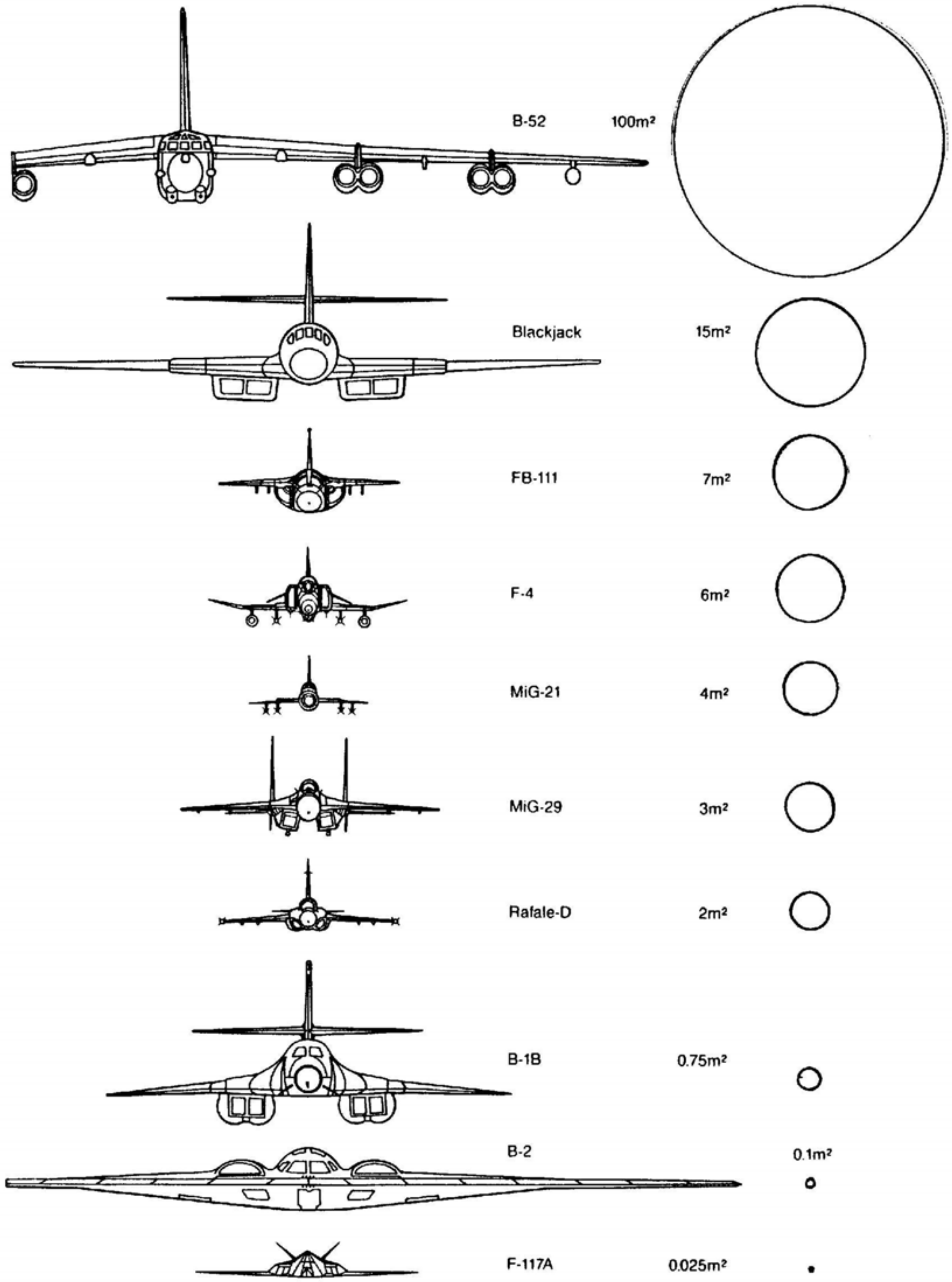
Using RAS to replace reflective structures and RAM to hide reflective components allows the stealth designer to cover most of the problems not covered by a low-RCS structural design.

A possible finishing touch for reducing the observed reflected radar energy is active cancellation. The basic idea would be to transmit a signal in all ways equal to the reflected wave but 180° out of phase with it. Thus a radar receiving the reflected signal and the cancellation signal would sum them and see nothing.

> Unfortunately, the technical problems are formidable. Aircraft—mounted sensors would have to measure the frequency, waveform, strength and direction of the signal to be countered. Complex signal processing equipment...would have to predict how the incoming wave would reflect, then create and transmit a suitable cancellation signal....Active cancellation systems have been discussed in technical publications and it is possible that equipment of this type is being developed for the B-2 bomber.[4]

Innovative use of shaping, materials, and electronic cancelling can be very effective in reducing RCS.[5]

Physical Size Compared to RCS



In terms of military utility, RCS matters little if an aircraft is broadcasting its own signals for the enemy to hear. Airborne radar, navigation, and communications systems put out energy in the micro— and radio—wave bands of the electro—magnetic spectrum. Likewise the engine exhaust, hot engine parts, and even portions of the aircraft skin heated by air friction emit at the infra-red end of the spectrum. As stealth designers become more successful at suppressing the reflected radar signature of an aircraft, minimizing these aircraft—produced signatures becomes ever more important.

Radar serves as an extension of the pilot's eyes in most modern warplanes. Airborne navigation radars identify landmarks upto two hundred miles away. Air-to—air radars search for and track multiple targets in vast quantities of airspace. Other radars provide high resolution images of ground targets for attack, illuminate targets for semi-active air-to-air missiles, and provide terrain clearance allowing all-weather flight close to the ground, day or night. While most of these radars have counter—jamming modes, the overriding design requirement has been how well they can see with little regard to how easily they are seen. With their wide search paths, high power output, and frequent revisit times, traditional radars would look like a flashing beacon on a stealth aircraft.

Stealth aircraft will rely on quieter, passive sensors, off–board senors, and low-probability of intercept (LPI) radars to replace traditional radars. For target acquisition and attack passive infra–red (IR) systems are in use and under development.

The Falcon Eye system currently being tested on the F–16 is a good example. A small turret mounted IR camera on the nose of the aircraft transmits images that are projected on the pilot's visor. Cockpit sensors calibrate movement of the turret to match the pilot's head movement so wherever he looks the appropriate IR picture is before him. According to pilots who have flown the system, it is as close to turning night into day as yet available. With its magnification capability, the system can also extend the pilot's vision day or night against ground or air targets.

Another quieter although not completely passive system, this for terrain avoidance and navigation, is the Digital Terrain System. An application of cruise missile technology, DTS works by comparing the output of a low power, narrow beam, downward looking radar altimeter with stored digital terrain information. By matching the sensed and stored data DTS can very accurately provide location and a depiction of terrain ahead of the aircraft allowing the pilot to safely fly at minimal altitudes. DTS could replace the terrain following radars on current deep strike aircraft such as the F-111 and Tornado.

Another solution is to move the sensors off the aircraft. Increased reliance on standoff platforms such as AWACS, Joint

STARS, and unmanned air vehicles will enable stealthy aircraft to know the air and ground situation in near-real time without activating their own sensors. At the other end of the engagement process, active sensors can be put on the weapons employed by stealth aircraft. The AIM-120 AMRAAM is a fully active radar missile that once launched uses its own radar rather than the parent aircraft's to guide on the target. Munitions with IR and millimeter-wave seekers are also under development for attack of ground targets.

Despite these advances stealth aircraft may still need onboard radar to be fully functional in a high paced combat environment. Consequently radar designers are working on radars that can see without being seen. LPI radars will probably have higher duty cycles with broader frequency spread and lower power level than traditional radars. Main beam sharpening and side lobe control will limit unwanted emissions. Time management will also be important.

> The chances of main beam detection will be reduced largely by transmitting only in short bursts, retaining the radar "snapshot" between transmissions, and updating target tracks by dead reckoning.[6]

As these technical advances reduce the radar's signature, emissions from other navigation and communications systems will become more threatening. As with the radar both reliance on off-board systems and muffling of onboard systems promises a solution. The Global Positioning System provides emission free navigation data. The Joint Tactical Information Distribution

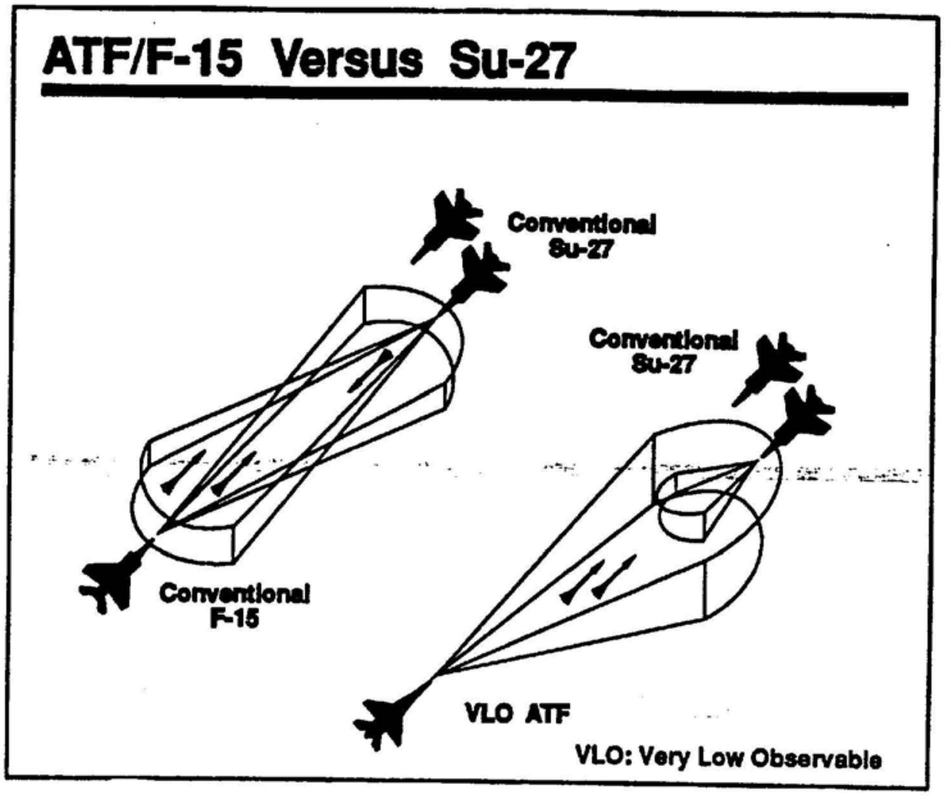
Systems (JTIDS) will provide a data link capability much harder to identify than current radios and with a much more rapid transfer of data than traditional voice communications. Directional antennas, adaptive power output, and digitized burst transmissions will make necessary voice transmissions harder to intercept.

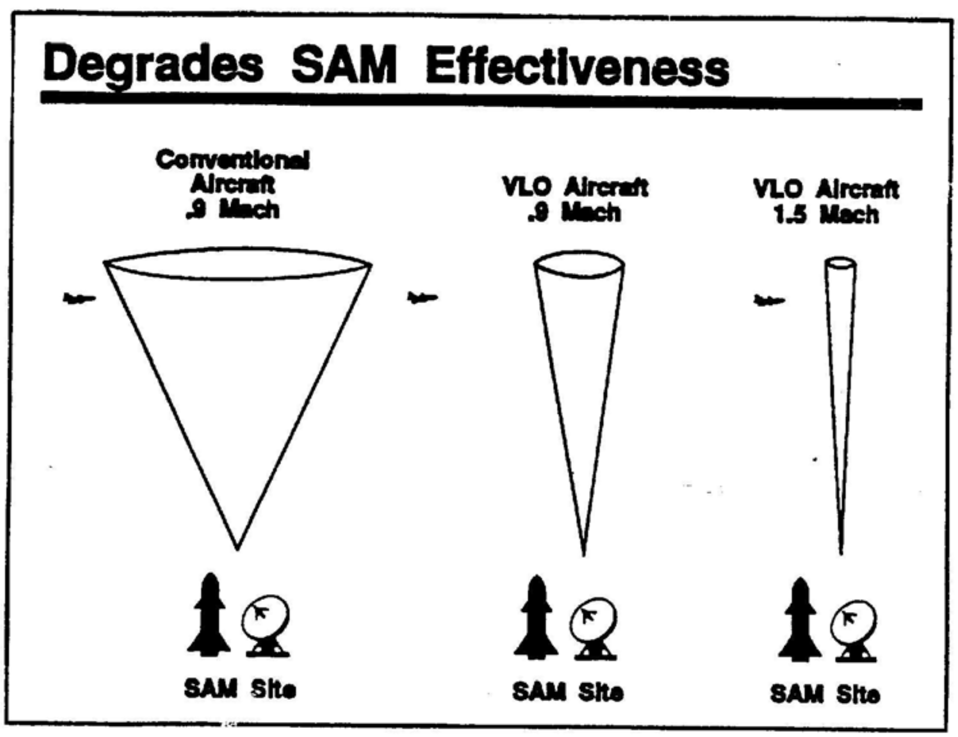
Having suppressed emission from the radar and radio, the stealth designer must turn to the engines and their signature in the IR spectrum. The first step is to get an engine that creates less heat. The worst heat offenders are afterburners. Creating very high thrust engines that don't require afterburners is a stealth priority. Another solution is to mix cool air with the combustion products before releasing them in the airstream. This is a typical function of high-bypass turbo—fan engines. The exhaust nozzles can also be shaped and hidden to reduce and mask their IR signature.

But what is the effect of stealth on the battlefield? The perception that stealth will be "invisible" is wrong. Reduced RCS means reduced detection range, not no detection. Stealth can however reduce radar detection range to a militarily significant level.

> Low-observable technology is revolutionary. Radar systems for detecting, following, and attacking air and surface vehicles are relatively cheap and enormously effective — except when the vehicles incorporate Stealth. Military vehicles that incorporate enough low-observable technology make existing radars rather ineffective. Replacing those radars with systems that can detect, track, and attack stealthy vehicles is technically difficult, expensive, and time—conuming (the more so since low-observable technology is still evolving).[7]

The reductions in detection range possible by the application of low-observable (VLO) techniques are shown below.[8]





COUNTERS TO STEALTH

Debates continue to rage on whether effective counters to stealth can be found. The most vocal nay—sayers have been the proponents of other systems, notably European aircraft designers. The Air Force has itself studied the problem.

> The capability of Soviet research and development to make near—term improvements or technological breakthroughs in countering stealth technology appears to be highly remote, according to a USAF "Red Team" that has studied more than 40 counterstealth concepts since being formed in 1981. The Team has stated that it found no "Achille's heel" that would negate the value of stealth technology in the foreseeable future.[9]

Whatever the case, the premise of this paper will be that stealth will work as advertised and that any necessary counter—counter measures will not be so onerous that they negate stealth's basic value.

Stealth Applications

Having reviewed the technology of low-observables its time to look at the aircraft programs using them. The US has announced plans for five stealth aircraft over the next 15 years. These planes range from currently operational to still in the concept development stage. Additionally there are two variations for cross—service use planned.

The F—117 Night Hawk entered service in 1983, under very tight security, and the buy of 59 aircraft is now complete. Designed as a precision, deep—strike aircraft, the subsonic F-117 relies on many of the technologies already described to penetrate and attack high-value enemy facilities.

> The F-117A's designers...relied on the concept of faceting to give the aircraft its minimal radar signature....Much of the aircraft's external surface is made of composite radar—absorbent materials....The engine intakes and exhaust nozzles are above the wing and rear fuselage, respectively, to shield them from infrared seekers below.....Navigation is believed to be by high-precision INS and GPS, with FLIR and DLIR (downward-looking infrared) radar housed in a stearable turret...[10]

While F—117 pilot have shunned the "Wobbly Goblin" moniker first hung on their aircraft, the 22,000 lbs. of thrust provided by its two non-afterburning engines is hardly enough to give this F-15 sized aircraft the sustained maneuverability of a fighter aircraft. Indeed action by the House Armed Services Committee to include monies for upgrading the F-117’s engine in the FY 1992 budget tends to confirm limited-thrust rumors[11]. Payload size may be another limitation for the F-117 that is not shared by the second US stealth aircraft.

The B-2A is the application of stealth technology to the intercontinental strategic bombing mission. With its high sub-sonic speed, high or low altitude penetration capability, and an unrefueled range exceeding 6000 miles, the B-2 can deliver upto 20 nuclear weapons or 80 conventional 500 lb bombs, cluster bombs, or "a precision-guided munition with classified capabilities"[12] deep within enemy territory from distant bases. The tailless flying—wing configuration, smooth rounded body, and hidden engine exhausts speak to the B-2's stealthiness, Currently in limited-production while final

testing is completed the B-2 is scheduled to enter operational service in the mid-1990's. A production run of 75 aircraft is currently planned.[13]

At the other end of the spectrum the Advanced Tactical Fighter (ATF), the F-22 Lightning II, is to be the stealthy air-superiority fighter for the USAF. Currently entering full-scale development, the F—22 is slated to enter service just after the turn of the century replacing the F-15 as America's premier air—to-air machine. Combining stealth, advanced avionics, and supercruise (the ability to reach and fly at supersonic speeds without afterburner) with increased maneuverability, the F-22 promises to be an intimidating aerial opponent. A naval version of the ATF is to follow the USAF version by three to four years to provide a carrier based replacement for the F-14.

The companion in development to the ATF was to have been the Advanced Tactical Aircraft (ATA). Cancelled during development due to program cost and schedule overruns the Navy's A-12 Avenger II was to replace the A-6 for the Navy while a follow-on Air Force version would replace the F-ill. The requirements for the A—12 were rigorous.

> Compared to the Navy A-6E that it is designed to replace, the A-12 is to have a forty percent larger payload and a sixty percent larger combat radius, plus a turn rate better than that of the F/A-18 and one—fifth of the Hornet's vulnerability.[14]

The future of the ATA requirement is currently in doubt with the Navy intensely studying alternatives for an A-X. One of the

most promising alternatives is to capitalize on the ground attack capabiltiy embedded in the F-22 and make the naval version dual—role much like the F-15E. The cost savings in development and operations due to a high degree of commonality would be significant. Lack of a new tactical bomber leaves a big gap in the line of new stealth aircraft.

The final stealth aircraft under discussion, a multi—role fighter to replace the F-16 and, possibly, the F/A-18, will not enter concept definition until 1992. Current proposals range from an entirely new aircraft to a modified F-16 retrofitted with ATF technology.

> OSD officials are telling the Air Force a new multi—role fighter could be developed in five years and produced in seven or less, for only a 10% to 20% cost increase over the F-16....The biggest feature of the new multi-role fighter would be it new stealthier wing. It probably would weigh no more than 30,000 lbs, have a single engine (likely the ATF engine), include all the internal workings and same internal structure of the existing F-16 and possibly include a portion of the ATF avionics.[15]

Despite OSD's predictions, in the current budget environment and with the almost inevitable delays in development, it seems unlikely that a stealth multi-role fighter will be operational before 2005 at the earliest.

SUPPORTING TECHNOLOGY

Three trends in technology will greatly effect how stealth is used on the battlefield. The maturation of affordable, flexible precision guided munitions (PGMs) has markedly increased the lethality of air attack. Targets that required

hundreds of sorties in World War II or dozens in Viet Nam can now be attacked by a single aircraft with a high probability of success.

As important are the improvements in aircraft reliability and maintainability made over the last decade. While much of the improvement in operational ready rates can be attributed to adequate stockage of spare parts credit must also be given to the efforts to design reliability into new aircraft and weapons. The USAF's RIM 2000 program has led this effort and is paying dividends. Its Ultra-Reliable Radar (URR) forms the basis for the ATF radar.

> Technicians came up with a practical way to produce a radar with 2,000 individual transmit/receive antenna modules...which boasts much-improved range compared to current radars. It is also far more reliable — the expected mean time between failures for the entire array comes to 2,000 hours, and for each T/R module an astounding 8,000 hours.[16]

Whatever the reason, the increase in reliability can not be denied. In the early eighties, Air Force units were having difficulty keeping two-thirds of their aircraft fully mission capable in peacetime. According to after action reports from the Gulf War, fighter units were reporting above 90% ready-rates after forty days of war.[17]

The most pervasive technological change effecting the environment in which stealth aircraft will operate will be the revolution in information gathering and handling made possible by micro—electronics. Space—based sensors, navigation systems, and communications channels provide new dimensions in C3I both

for commanders planning a campaign and aircrews fighting it. standoff sensor platforms like AWACS and Joint STARS add to the currency, accuracy, and completeness of the airman's picture of the battlefield. Computer-aided intelligence fusion cells can collect, analyze, and display multi-source intelligence in easily understandable graphics and feed directly into digital mission planning systems so crews can plan more quickly and effectively.

STEALTH'S IMPACT ON TACTICS

In order to counter the radar—based Integrated Air Defense Systems (IADS) expected on a modern battlefield aircrews devised tactics to minimize exposure to radar threats. As those threats multiplied to provide overlapping and redundant coverage, tactics shifted from individual flight tactics to strike packages complete with support aircraft dedicated to engaging the radar threat. A few words about these tactics are important before looking at the changes made possible by stealth.

The simplest way to defeat radar threats is to fly where they can't see you. By flying very close to the ground, aircrews could take advantage of intervening terrain or even the curvature of the earth to shield them from radars. Until the advent of doppler radars most radars still had problems tracking targets at very low altitudes. As a result US crews trained down to 100' above the ground in high speed tactical aircraft.

The price for low altitude tactics is high. The denser air at low level reduces maximum speed and range. In an F—4 for

example, fuel consumption at sea level is about twice that for the same speed at cruising altitude around 30,000 feet. Maneuverability is limited because the first move has to be up and there is no opportunity to trade altitude for airspeed as would be the case at higher altitude.

The crew workload at very low altitude is also extremely tasking. The worst threat is the ground itself; radar systems may be good but the Pk of the ground is real close to 100%. At 600 knots and 100'up a pilot who drops the nose a mere 20 will die in less than three seconds. Proximity to the ground also taxes the crew's navigation and target acquisition skills. Landmarks and targets are more difficult to find. Onboard radars and other sensors have limited range being effected by the same terrain a the threat radars.

Weapons and their delivery are also effected by low altitude. Shallow impact angles can cause the bomb to break up before exploding or even broach in which case it bounces rather than functioning. Low altitude deliveries can make dispersion of submunition from cluster-bombs sub-optimal. For hardened targets the impact angle may not allow penetration prior to explosion. To overcome the acquisition and weapons problems associated with very low altitude deliveries, aircrews use "pop to dive" tactics requiring a rapid climb from the sanctuary of low level followed by a shallow diving delivery. The obvious problem is the increased threat exposure time during the delivery. Another problem with low level is the increased

threat of numerous unsophisticated threats such as optically tracked AAA and small arms fire. At very low level, an aircraft is in the "real time zone” of guns where the distances from gun to plane are so short that very little lead is required on the part of the gunner. All in all, low level can be a very unfriendly place.

In instances where the radar threat was just too dense or the AAA and small arms threat to great, aircrews were forced to leave low altitude and operate in fully supported attack packages at higher altitudes. Support for air packages had to cover all the expected threats. Jamming aircraft such as the EF-111 and EA-6B would attempt to degrade enemy early warning and ground-controlled—intercept (GCI) radars forcing surface—to—air missile (SAM) systems into less effective autonomous operations. The SAM batteries then were attacked or intimidated into shutdown by SAM hunting Wild Weasel F-4Gs using anti-radiation missiles and often operating in hunter-killer teams with conventionally armed fighter-bombers. To counter the increased threat from interceptors, Combat Air Patrol (CAP) fighters had to sweep in front of the package and in many cases escort it through enemy defenses.

The problems with package tactics are numerous. Planning, coordination and control of such a large group of aircraft is complex, cumbersome, and time—consuming. Much of the flexibility inherent in airpower is lost. The overhead of support aircraft for a few attackers is tremendous. In Viet

Nam, the support aircraft often equalled the attackers in number. For the 1986 raid on Libya almost 100 aircraft were launched to put less than two dozen over the targets. Finally, package tactics do not offer immunity to radar threats. Some SAMs still get fired and some interceptors still get through.

Worse yet, the high-value support aircraft themselves are subjected to the threats as they escort the attackers throughout the mission. A hybrid tactic for dense threat zones is to have the support team concentrate on a single area to blast a hole in the defenses through which the attackers can penetrate the worst of the defense and then rely on low level individual flight tactics to get to, acquire, and attack a target. While better than unsupported penetration, this tactic still leaves the attack pilot to grapple with most of the problems of low level flight. It also makes penetrator somewhat predictable by flagging the area through which they will enter and allowing an enemy to mass mobile systems to fill the gap.

By greatly reducing the radar-based threat, stealth will give the airman the freedom to operate outside of the low altitude structure without the shackles of package tactics. Route selection choices are also expanded as penetration can occur outside of support aircraft-cleared corridors and areas too hot to enter for conventional aircraft can be transited safely.

As a result more effective medium altitude deliveries from a wider choice of approach paths can optimize weapons delivery and

take full advantage of the potential lethality of precision weapons. Aided by the standoff sensors already discussed and free to loiter at altitudes from which target acquisition is possible over a wider area, armed reconnaissance again becomes a viable tactic against mobile targets.

By freeing attackers from package tactics stealth will also regain for the pilot the flexibility of single-ship or simple flight (2 or 4 ship) missions. This will enable more targets to be struck simultaneously and the precision bombing capability will ensure a high degree of destruction. Perhaps most importantly, stealth will give the attacker an element of surprise that has long been missing from air attack missions. Denying the enemy the time to either employ his defenses or protect his assets would pay big dividends.

In the air-to-air environment the stealth and speed of the F-22 will greatly broaden the tactics available to the fighter pilot. The multitude of advantages offered by "seeing" the enemy before he sees you have become axiomatic in aerial warfare. The "first-look, first-kill" capability gained from its superiority in the radar detection arena will make the F—22 an overpowering opponent in aerial engagements. Supercruise will allow it to range the battlefield more quickly and broadly. In many cases it will have a speed and maneuverability sanctuary where adversaries can not operate. Perhaps more importantly, stealth will give the F-22 the ability to approach an opponent undetected and attack with surprise from a position of sustained advantage. The effect could be crushing.

Stealth will also op en, or more precisely re-open, a group of tactical options long denied by the existence of radar based IADS. Due to the presence of numerous SAMs and AAA, often with overlapping coverage, most air-to—air tactics have preceded from a defensive posture. Fighter pilots fly CAP on the friendly side of the lines either protecting specific high-value targets or orbiting in areas picked to enable swift response to enemy penetrations. The relative immunity to ground threats afforded by stealth will let the fighters out of this defensive posture to seek out and destroy enemy aircraft wherever they can be found.

Sweep and escort (probably detached escort) tactics can once again be practiced to support strike packages. Deep offensive flights can attack high-value platforms and disrupt all air traffic well behind enemy lines. Air denial missions could trap enemy aircraft on their fields knowing that on takeoff—roll an AMRAAM could be on its way. Development of tactics to fully tap the potential of the F-22 will probably have to await its entry into service but the possibilities will keep tacticians busy for some time.

In terms of flight and package tactics, the combination of stealth and non-stealth aircraft could provide an enemy with difficult dilemmas. In a ground attack scenario, a missile site guarding an airfield would have a no-win decision to make if an attack package possibly including stealth were approaching. If he boosts his power and gains to attempt to find the stealth, he

opens himself to jamming and lethal suppression by the package support aircraft. On the other hand, if he concentrates only on what he can see, a just the wrong moment he may be suppressed by a surprise stealth attack. By shutting down the threat at the moment the attacks begins, the stealth aircraft ensures much higher destruction levels and lower losses. Likewise, the presence of the conventional aircraft makes it impossible for the defenders to concentrate on the elusive stealth threat.

Summing up, at the tactical level stealth will lead to more flexible, and lethal operations. Aircraft will be freed from reliance on low level flight and will not necessarily be tied to cumbersome attack packaging. Individual aircraft and flights will be able to operate independently denying an enemy fore-warning of potential targets. Co-ordinated tactics with conventional aircraft can synergistically improve the mission effectiveness of both. Stealth will increase the offensive bent of air tactics and provide surprise at the fighting level.

STEALTH AT THE OPERATIONAL LEVEL

In testimony on Defense Policy before the House Armed Services Committee in April of 1991, former Undersecretary of Defense (Research I Engineering) Don Hicks told Rep. Aspin "The combination of stealth and PGM...[has led to]...success in the Gulf and fundamental changes in how the armed forces do business." He went on to say, "The F-117, flying 1–2% of the sorties,... [inflicted]...half the damage to strategic targets." Subsequent Central Command reports show that in the first

critical hours of the war the stealthy 2% of the force took out 30% of the targets destroyed and was the only force to attack "downtown Bagdad" during the war. While the increased efficiency and access of stealth and PGMs is important, it is only part of the story.

Traditional air campaigns consist of five, usually sequential, phases:

> Buildup — forces move to the area of conflict; secure, and improve operating bases and supply lines. Defend against enemy attacks.
>
> Gaining air superiority — secure freedom of action for ground, naval, and subsequent air operations by denying an enemy use of airpower to attack friendly forces or to interfere with their operations. Counter-air missions including CAP, airfield attack, Suppression of Enemy Air Defenses (SEAD), and counter-C3I mission predominate.
>
> Strategic offense - attack key enemy centers—of—gravity to reduce ability and willingness to wage war. Targets include key political and economic power centers and military targets above the theater level or ones with strategic potential.
>
> Isolation and preparation of the battlefield - reduce enemy surface commander's options by cutting off resupply, reinforcements, and reducing combat capability of his force.
>
> Support of surface operations — provide support to surface commanders through direct support and focused coordinated attack missions.

While these stages may not all be necessary or possible in a particular campaign, they provide a logical framework for examining the impact of stealth. One should also remember that the stages may well overlap and the distinctions between them are artificially distinct; many targets would be appropriate for more than one stage of the campaign.

Stealth will have impacts on each of these stages. More importantly stealth will allow for the acceleration of the process and add flexibility to campaign planning.

During the buildup of forces the effect of stealth aircraft range from rudimentary to quite significant. The increased reliability of the aircraft will reduce the amount of airlift required to move a squadron into position. The use of precision weapons will reduce the amount of munitions necessary to disable any given target set. The ability to operate without the entire overhead of support aircraft means fewer of them need to be in theater prior to the initiation of offensive operations aimed at securing the base of operations.

In defending the air over a buildup the F-22 will have obvious advantages already discussed. Its ability to seek out and destroy enemy air and to disrupt enemy attack packages as they form adds a new dimension. The availability of the Navy ATF will provide much of the same capability in power projection scenarios particularly if the need for fleet defense can be minimized. However neither version of the ATF will be available in the next decade so what about the mean time?

Protection of the buildup area is a mission to which the F-117 and B-2 can significantly contribute. Closing airfields, cutting high-speed lines of approach, disrupting enemy C3I could all be missions accomplished by Stealth attack aircraft based outside the range of enemy actions yet requiring minimal support to strike the enemy. It is in this area that the lack of a

program for the ATA requirement is perhaps most keenly felt. The potential powerful carrier punch would be sorely missed.

As BGen Buster Glosson, the chief air planner for the Gulf War, was quoted in the previously mentioned Congressional Defense Policy hearings, "Long range bombers may offer the only way to shut down enemy aircraft during the buildup." The Gulf War proved again the viability of long range support of theater warfare with B—52s flying missions from as far afield as Spain, the UK, and the continental US. The enhanced survivability of the B-2 and the reduced perception of a Soviet nuclear threat would indicate a greater likelihood of the B—2 being released from its strategic nuclear retaliatory role for theater purposes. To make this potential a reality, the services will need to develop procedures to enhance the responsiveness and flexibility of these long-range assets.

Stealth would have a great impact on the air superiority portion of a campaign. In some way stealth provides its own degree of air superiority. To the extent that stealth operations are free from interference by radar—dependent IADS, the air commander already has the freedom of action which is the goal of gaining air superiority. The goal of the campaign then becomes obtaining that same freedom of action for conventional aircraft and denying the enemy the ability to interfere with friendly surface operations.

Stealth fundamentally changes the counter-air phase by increasing its rapidity and shock. Traditionally, air would attempt to find a weakness in the defenses, use support and attack aircraft to clear a corridor, and push through an attack package to hit airfield complexes while providing SEAD and counter-C3I missions. Repeating this method would eventually roll up an enemy air force and the cumulative effects of the SEAD campaign would reduce the SAM threat.

With stealth, the counter-air campaign can begin with a massive blow to the center of the enemy's IADS, shattering its cohesion, and providing the opportunity for conventional attack packages to deliver a decisive blow without the hindrance of coordinated opposition. F-117s could simultaneously attack large numbers of the most critical C3I nodes and long-range sensor sites. B-2s could shutdown airfields and SAM sites, trapping aircraft on the ground, defenseless to attack by conventional aircraft. F-22s and their Navy cousins could cripple high-value airborne sensor platforms, blinding the enemy, and then sweep the sky of unsupported defenders. While the IADS was paralyzed by this onslaught, conventional aircraft would be free to deliver crippling body punches to the remaining air defense assets. All this with a quickness and decisiveness that would likely shock the defender. With air superiority won, the truly offensive, war-winning stages of the air campaign could begin.

The listing the strategic phase after the air superiority phase should not be taken to mean a stringent sequential relationship, particularly with the advent of stealth and precision. Strategic attacks are decided upon based on the potential benefits and risks, both military and political. The combination of stealth and precision increases the former and decreases the later resulting in a higher likelihood of an early start and lower cost for a strategic phase.

F-117s and B-2s could strike deeply and effectively from the very outset of hostilities. National leadership, command and control nodes, communication centers, power production and distribution systems, and key economic assets could be vulnerable to destruction with non-nuclear precision munitions. Furthermore the ability to do so at any time during the conflict without first investing in achieving air superiority over those strategic targets, both saves counter—air expenditures and provides a continuing threat of escalation without undue cost or reliance on nuclear weapons. This fact alone may provide deterrence at the regional conflict level much as strategic nuclear power has amongst the superpowers for the last four decades.

Indeed one of the more intriguing questions is the extent to which precision guided conventional weapons on stealth aircraft could replace nuclear weapons in a counter—force role. CNN showed graphically the ability of single stealth sorties to completely demolish modern, hardened, underground bunkers. One

must wonder how much more difficult hardened underground missile silos would be. While a force of 60 F-117s and 75 B—2s could not be considered a "first strike" threat to the Soviet Union's nuclear forces, it would pose a significant threat to most other nuclear powers. Such an ability to eliminate an enemy's weapons of mass destruction without crossing the nuclear threshold may become increasingly important in regional conflict as nuclear proliferation proceeds apace.

Stealth's role in isolating and preparing the battlefield will involve less of a change than in previously discussed stages of the campaign. Stealth will be able to cut critical lines of communications earlier in the campaign and at lower cost than was previously possible. The Gulf War showed clearly the F-117s bridge busting capability and that of other precision bombers once air superiority had been gained.

A limited number of stealth aircraft would also make the concentration of combat assets a risky alternative thus forcing an opponent to follow stringent dispersion policies. This loss of ability to mass forces for attacks of counter—attack would severely limit an opponents freedom of action. The necessity to disperse air defense assets with the forces would dilute their effectiveness and place significant stress on the command and control network.

As the number of stealth platforms increases with the eventual introduction of an ATA and multi-role fighter, the advantages of stealth will be felt more keenly in this stage.

Immunity from most sophisticated defenses would increase the flexibility and tempo of the operation allowing more focused efforts and more timely shifting of effort to suit changing needs of the joint commander. For the near future the bulk of this effort will remain with the more numerous conventional aircraft enjoying the assistance of stealth platforms.

Currently programmed stealth platforms will also have limited but not insignificant impact on the support of surface operations. Their limited numbers and mission specific design will ill suit the first stealth platforms to traditional Close Air Support (CAS) roles. Properly used they can, however, contribute greatly to the ground commander's mission success. In instances where massive firepower, precisely applied at a specific time and place would be important, the assuredness of stealth attacks may allow more reliance than before on an assist from the air arm. Using this potential will require higher levels of understanding and coordination than has been required before between air and ground planners.

As has been shown, stealth in combination with precision weapons will impact the planning and execution of every stage in an air campaign. In some cases the change is fundamental; in others more marginal. Emerging from the experience of the Gulf there is, however, a line of thought that would basically change the focus and structure of the air campaign based largely on the capabilities of stealth and precision. Not yet blessed or even published, it would apply the theory of "maneuver warfare" to

the air campaign. Enter Hyperwar!

The basic premise of hyperwar is that with stealth and precision an enemy can be overwhelmed and paralyzed with shock as his most important power centers are simultaneously destroyed by surprise attacks. By rapidly shifting the focus of such an air campaign, planners would keep an enemy off balance and make work-arounds useless before they could be instituted. Aimed at whatever provided that enemy's strength, hyperwar would unhinge his decision making process leaving additional centers of gravity vulnerable. The part played by stealth is central.

According to Col John Warden, Deputy Director for Warfighting, Hq USAF, and the man credited by CNN commentator retired Maj. Gen. Perry Smith with providing the theoretical basis for the Gulf air campaign,

> Stealth returns genuine tactical and operational surprise to warfare, and precision enabled us to destroy virtually every critical strategic node [in Iraq] with only a few sorties....The offense has been returned to a primary place in military operations, and that revolution has occurred in a conceptual way as much as a technological one.[19]

As stealth continues to enter the inventory and the risks of decisive offensive actions decrease, the acceptability and utility of hyperwar as a model for air campaigns will continue to grow. The limiting factor may well be the number of airframes available to accomplish the simultaneous onslaught so central to overwhelming an enemy. Again the lack of an ATA is apparent. The ability to use conventional aircraft in conjunction with stealth to provide the required mass will be

central.

STEALTH AT THE STRATEGIC LEVEL

At the highest level, the protection of the United States from massive thermo-nuclear attack, stealth will contribute but not significantly alter, the concept of deterrence through nuclear sufficiency that is the bedrock of American defense strategy. The assured penetration capability of the B-2 will enhance the retaliatory capability of the nation in spite of any foreseeable defenses. The F-22 with its improved speed and radar capability would also improve strategic defense against bombers and cruise missiles. These capabilities, important as they are do not significantly change how the nation conducts her security affairs.

One area that may well be effected is the relationship with friends abroad and their needs for modern military aircraft. Caught in a squeeze between the need to fund stealth development for all the reasons previously discussed and the budget drive force cuts, the USAF has cancelled all fighter buys beyond 1993 and is undertaking no new major development projects on existing designs. The resulting gap in front line fighters for export worries many.

> There's no way the US could offer planes like the ATF or A-12 for sale abroad until after they're fully deployed with our services. That means 2005 to 2010... There's a growing disconnect between the marketability of our current fleet, the arrival of these new aircraft, and what can be sold on the international market. If we fail to keep pace by modernizing the F—15, F-16, and F-18, we have a real dilemma, because the other ones [ATF, A-12, etc.] are still nowhere in sight. — Dennis Kloske, Undersecretary of Commerce[20]

> Foreign sales? It certainly does worry me. There's a possibility with ATF, but nothing else: that's the only thing we'll have in production. Nothing until the ATF can be exported after the turn of the century. Does it bother me? Hell, yes! There not going to be a foreign sales base for new aircraft until the first half of the next decade....[and]...You won't see any dollars for a multirole aircraft until the last half of the 90's.
> - John J. Welch, Asst. SecAF (Acquisition)[21]

Aside from the commercial effects, balance of payments, and industrial base concerns from potentially loosing a traditional foreign market, there are some significant military and political cost involved in this situation. Foreign military sales provide the US with both access to and leverage over foreign governments and militaries. There is also am element of national prestige at stake that should neither be overstated or dismissed. Finally, Loss of sales could impact the interoperability we enjoy with our allies at a time when operating effectively with them in regional crises is becoming increasingly important. It is a problem that needs addressing.

Stealth's biggest impact at the strategic level is on the utility of military forces as instruments of national power. The political acceptability of military action will be increased by the attributes of stealth and precision; high likelihood of success, low risk of losses, and limited collateral damage. Utility is further enhanced by the increase in the feasibility of using forces with a smaller support requirement. At the larger level the greater likelihood of a quick, low cost victory, may entice some to use the military instrument more freely.

The increase in the utility of airpower may also reinforce the American aversion to the commitment of ground forces. To the extent that airpower as the military's main effort can achieve the desired outcome, political leaders will undoubtedly shy away from the more difficult and entangling commitment on the ground.

While those pursuing parochial service interests may overplay the point, in terms of Americans put at risk versus damage inflicted, air forces are hard to beat. The point has not been missed that in the Persian Gulf only 10% of the force was USAF and of that 50,000 certainly less than 5% were crew members flying combat missions. Adding the pilots from the other services, perhaps as much as 1% of the total force flew combat. Fully recognizing the critical part played by the other services, the fact that such decisive results could be achieved at such small risk of lives is astounding. And the results that 1% achieved were critical.

> Desert Storm marks a true turning point....the Persian Gulf War demonstrates that airpower has finally come of age after 7 years of overpromising because stealth and precision have enabled air forces to apply force decisively in large—scale conventional wars.
>
> -Edward Luttwak, Center for Strategic and International Studies[22]

CONCLUSION

Stealth technology, applied to military aircraft, will have the ability to change how airmen fight. By shrinking the threat of radar based systems, stealth will provide a broader choice of tactics increasing the effectiveness and survivability of

aircraft. In conjunction with associated technologies, primary among them precision guided munitions, stealth will change each of the stages of the air campaign emphasizing shock and decisiveness at the operational level. Aiming at an enemy's decision-making capability, stealth-based hyperwar will aim to shock and paralyze an opponent while he is struck decisively. At the strategic level stealth will increase the utility of the military instrument by providing the nation's political leaders with a high probability of success for a relatively low risk.

Stealth is then one of the truly significant technological changes that impact all levels of war. The importance of anticipating and preparing for those changes can not be over-estimated.

Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur. - Giulio Douhet, Command of the Air

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